Title:

Effects of caffeinated gum on a battery of soccer-specific tests in trained university-standard male soccer players

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Abstract

The purpose of this study was to determine whether caffeinated gum influenced performance in a battery of soccer-specific tests used in the assessment of performance in soccer players. In a double blind, randomised, cross-over design, ten male university-standard soccer players (age 19 ± 1 y, stature 1.80 ± 0.10 m, body mass 75.5 ± 4.8 kg) masticated a caffeinated (200 mg; caffeine) or control (0 mg; placebo) gum on two separate occasions. After a standardised warm-up, gum was chewed for 5 min and subsequently expectorated 5 min before players performed a maximal countermovement jump, a 20 m sprint test and the Yo-Yo intermittent recovery test level 1 (Yo-YoIR1). Performance on 20 m sprints were not different between trials (caffeine: 3.2 ± 0.3 s, placebo: 3.1 ± 0.3 s; $p = 0.567$; small effect size: $d = 0.33$), but caffeine did allow players to cover 2.0% more distance during Yo-YoIR1 (caffeine: 1754 ± 156 m, placebo: 1719 ± 139 m; $p = 0.016$; small effect size: $d = 0.24$) and increase maximal countermovement jump height by 2.2% (caffeine: 47.1 ± 3.4 cm, placebo: 46.1 ± 3.2 cm; $p = 0.008$; small effect size: $d = 0.30$). Performance on selected physical tests (Yo-YoIR1 and countermovement jump) was improved by the chewing of caffeinated gum in the immediate period before testing in university-standard soccer players but the sizes of such effects were small. Such findings may have implications for the recommendations made to soccer players about to engage with subsequent exercise performance.

Key words: caffeine, gum, soccer, exercise performance, power, speed

Introduction

The prevalence of caffeine (1, 3, 7-trimethylxanthine; $C_8 H_{10} N_4 O_2$) usage within elite sport is high, with 75% of athletes having reported its use prior to and/or during competition (Del Coso, Muñoz, & Muñoz-Guerra, 2011). The ergogenicity of moderate caffeine doses (i.e., up to 3 $mg{\cdot}kg^{-1}$ of body mass [BM]) is well supported in athletic populations as numerous studies have shown that caffeine can enhance performance of endurance (Ganio, Klau, Casa, Armstrong, & Maresh, 2009), strength (Timmins & Saunders, 2014), power (Del Coso et al., 2012), agility (Jordan, Korgaokar, Farley, Coons, & Caputo, 2014), skill (Russell & Kingsley, 2014), and reaction time (Santos et al., 2014) tasks. Emerging evidence suggests that even lower doses of caffeine (<3 $mg{\cdot}kg^{-1}$ BM) have been shown to improve alertness, vigilance, enhance mood and cognitive processes both during and after exercise and these effects have been observed with few, if any, side effects (Spriet, 2014). Collectively, these improvements could enhance performance in soccer as it is a physically demanding intermittent sport that stresses both anaerobic and aerobic energy systems. During a match, players are involved in soccer-specific actions requiring repeated high-intensity running and high endurance capacity (Bangsbo, Mohr, & Krustrup, 2006). Notably, caffeine has been repeatedly shown to improve multiple sprint performance during simulated team sport activities (Schneiker, Bishop, Dawson, & Hackett, 2006) as well as improving passing accuracy (Foskett, Ali, & Gant, 2009) and jump performance in trained male soccer players (Del Coso et al., 2012; Foskett et al., 2009).

Caffeine acts as an adenosine receptor antagonist, thus reducing the perception of effort at a given intensity and increasing central drive (Davis et al., 2003). Traditionally, caffeine has been provided in a capsule or beverage form approximately one hour prior to exercise, with peak plasma caffeine concentrations realised 15 to 120 min post-ingestion (Magkos & Kavouras, 2005). Caffeine from chewing gum, however, is more rapidly absorbed into the blood stream via the buccal mucosa, resulting in a faster onset of effects compared to more traditional modes of ingestion (i.e. 5 min versus 45 min, respectively) (Kamimori et al., 2002). Such responses may be beneficial for team sport athletes in scenarios where limited time for nutritional interventions exist at specific points in the competition day (e.g., the end of the warm-up, at half-time, or for substitutes required to enter competition with limited notice), but where ergogenic effects are desired.

Several studies have examined the effects of caffeinated chewing gum on exercise performance (McLellan et al., 2005; Oberlin-Brown, Siegel, Kilding, & Laursen, 2016; Ryan et al., 2013) and the findings have been equivocal. Some have found that caffeinated gum can enhance cycling (Ryan et al., 2013) and running (McLellan et al., 2005) performance as well as pacing strategies (Oberlin-Brown et al., 2016), whereas other studies reported no benefit to cycling performance (Oberlin-Brown et al., 2016). Surprisingly, limited studies have examined the effects of caffeinated chewing gum on specific components of soccer performance, despite the ergogenicity of caffeine relative to key performance indicators in soccer and the practicality of this mode of administration. Soccer teams typically use a battery of fitness and performance tests to assess a player's performance (e.g., the Yo-Yo Intermittent Recovery Test Level 1 [Yo-Yo IR 1] is used to test aerobic fitness and has previously been shown to correlate with high intensity distance covered in a match (Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009), the countermovement jump test is used to assess explosive lower body power output which may relate to the ability to jump and head the ball (Lara et al., 2014) and the 20 m sprint to measure speed (Turner et al., 2011)) at various times throughout the season (e.g., pre-season). Accordingly, it was hypothesised that if the caffeinated gum could enhance performance on these tests, the implications for transferability to actual match-play could be examined. Therefore, the purpose of this study was to determine whether a low dose of caffeine (200 mg) provided in a chewing gum would improve performance in a battery of soccer-specific tests. A dose of 200 mg was chosen because this aligns with manufacturer's guidance on use and because some soccer matches occur late afternoon/evening when the use of a higher dose might perturb sleep.

Methods

Design

A double-blind, randomised, cross-over design was used where participants were randomly allocated and counterbalanced into caffeine and placebo conditions using a random sequence generator (GraphPad Software Inc. USA). University-standard male soccer players participated in the study and data were collected between March and May 2017 towards the end of the university competitive season. The battery of soccer-specific tests included the Yo-Yo IR 1 which is used to test aerobic fitness, the countermovement jump test which is used to assess power, and the 20 m sprint which is used to measure acceleration (Turner et al., 2011). These tests have been shown to be reliable with typical co-efficient of variations for the Yo-Yo IR1, countermovement jump, and 20 m sprint tests of 4.9% (Krustrup et al., 2003), 2.8% (Markovic, Dizdar, Jukic, & Cardinale, 2004) and 2.7% (Hulse et al., 2013) respectively.

Participants

In order to estimate the sample size required for this study, data from a previous investigation that examined the effects of caffeine on the Yo-Yo IR 2 test (Mohr, Nielsen, & Bangsbo, 2011) was used. The power equation used an alpha level of 0.05 and power was set at 0.84 and it was calculated that a sample size of 7 was required for this study. Ten male university-standard (4 ± 0.9 years of competitive soccer experience, training 333 ± 28.7 min·wk^{-1}) soccer players (age 19 ± 1 y, stature 1.80 ± 0.10 m, body mass 75.5 ± 4.8 kg) volunteered for this study. None of the players that participated in this study had any major or minor injuries nor any medical complications. During recruitment, players were asked if they had ever experienced adverse effects from caffeine ingestion and ones that had suffered negative effects were excluded. Players were members of the University's second XI team and played in one competitive match per week throughout the season. The study was approved by an institutional Health and Wellbeing Faculty Ethics Committee and all of the participants completed an informed consent and pre-screening questionnaire prior to taking part in any testing procedures.

Procedures

To control for diet and prior physical activity over the two testing sessions, players were asked to record food intake and activity for 48 h before each main trial using written food and activity diaries. Players were instructed to replicate the dietary intake and activity profiles recorded before the first testing session prior to the second visit. Players were asked to avoid alcohol and strenuous exercise for two days before each visit. Diaries were checked to ensure compliance and we were satisfied that all of the participants adhered to the instructions given and that the food and drinks consumed before each trial were the same. Data collection for both placebo and caffeine trials occurred 72 h after a competitive match where training was replaced with a testing session. Placebo and Caffeine trials were separated by 2 weeks. Players were required to visit the testing venue on two occasions separated by seven days where caffeine was limited to 100 mg per day throughout the washout phase. This was checked by the investigators by asking the participants verbally. Health screening (PAR-Q), and collection of participant demographics (whilst wearing minimal clothing) including age, stature (m; Leicester height measure; Invicta Plastics Limited, UK), body mass (kg; HD-327 digital scales, Tanita, Japan) and playing position were recorded. Players were instructed to wear appropriate sportswear that was identical for both visits. Players were familiar with the tests being administered because they undertook these tests at the start and mid-point of the football season as a standard part of their normal fitness testing.

Caffeine gum and placebo

The experimental gum contained 100 mg of caffeine per pellet (Military Energy Gum – Stay Alert, Arctic Mint flavour; Chicago, IL) was flavoured to a mint taste and contained 2 g of carbohydrate (sugar) per piece. The manufacturer produced placebo gum was identical in appearance and taste but was void of caffeine. Gum was administered immediately after the warm-up in a sealed opaque bag to aid double-blinding. Players were instructed to chew two pieces of gum (200 mg caffeine; 2.7 ± 0.2 mg·kg^{-1}) for 5 min; congruent with 85% of the dose being released within this time-frame (Kamimori et al., 2002). Gum was then collected in a disposable bag to ensure expectoration.

Soccer-specific Tests

Participants completed a 10 min soccer-specific warm-up (consisting of jogging, 10 m acceleration sprints, and speed/agility drills) before testing in an indoor sports hall with a polished concrete floor. The order of the tests performed was the countermovement jump test, 20 m sprints, and Yo-Yo-IR1; all completed within 30 min and five min passive recovery separated each test. Participants completed the tests in three separate groups (i.e. two groups of 3 and one group of 4).

After the warm-up, players carried out three countermovement jumps using an optical measurement system (Optojump Next; Micro Grate; USA). Each participant started the countermovement jump in the standing position, dropped down into the squat position, and then immediately jumped as high as possible. The first jump was used as a practice jump, and then two maximal jumps were performed, with 45 s rest between each jump. Countermovement jump height represents the maximal value achieved in the final two attempts. Five minutes later, the 20 m timed (Brower timing systems, USA) sprints were performed using three attempts; the first attempt serving as a warm-up, the second attempt at 70-80% intensity and the last attempt as the timed maximal sprint. Thereafter, the Yo-Yo IR1 test (Bangsbo, Iaia, & Krustrup, 2008) was performed and required 2 x 20 m shuttle runs that gradually increased in speed as dictated by audio signals. Each run was separated by 10 s active recovery where participants jogged around a cone positioned 5 m behind the start line. Two consecutive failures to reach the finish line before the audio signal indicated test cessation and the distance covered at that point was the final test result. All tests were performed with verbal encouragement from pertinent coaching staff and test administrators which was replicated for the second visit to ensure consistency.

Statistical Analyses

Statistical analysis was performed using SPSS 24.0 for Windows (IBM, Chicago, IL). The paired differences were checked for normality using the Shapiro-Wilks test. Differences in performance variables were compared between groups using a paired-samples *t*-test. Effect sizes were calculated for all of the dependant variables using Cohen's *d* formula using the pooled standard deviation. Effect sizes were interpreted using the classifications of 0.2, 0.5 and 0.8 as small, moderate and large effects, respectively (Cohen, 1988). Statistical significance was set at $p \leq 0.05$ and data are expressed as mean values ± *SD*s.

Results

Side Effects and Effectiveness of Caffeine Administration

There were no dropouts during the study and all of the players successfully completed two trials. At the end of the study, players were asked to write down adverse side effects and to evaluate whether they were given caffeine or placebo treatments. No adverse effects were reported and three out of the ten participants correctly identified the condition they were given suggesting that blinding was effective.

Yo-Yo Intermittent Recovery Level 1 Test

Caffeine enhanced performance on the Yo-Yo IR1 by 2% as players covered 35 m (95% CI 8.18, 61.82%) further distance on the test (caffeine: 1754 ± 156 m, placebo: 1719 ± 139 m; $p=0.016$; small effect: $d=0.24$).

***INSERT FIGURE 1 HERE ***

Sprint (20 m) performance

There were no statistically significant differences in 20 m sprint times between caffeine and placebo (caffeine: 3.2 ± 0.3 s, placebo: 3.1 ± 0.3 s; p=0.567; mean difference 0.11 s; 95% CI -0.31, 0.05 s; small effect: d=0.33).

Countermovement Jump Test

Figure 2 shows the mean and individual data for differences in countermovement jump height for caffeine and placebo. There were significant differences between the two conditions where caffeine enhanced jumping performance by 2.2% (caffeine: 47.1 ± 3.4 cm, placebo: 46.1 ± 3.2 cm; p=0.008, mean difference 1.0 cm; 95% CI 0.32, 1.67 cm; small effect: d = 0.30).

***INSERT FIGURE 2 HERE ***

Discussion

This is the first study to investigate the effects of caffeinated gum on a battery of soccer-specific tests that assess aerobic capacity, power and speed in university-standard soccer players. Although no effects on 20 m sprint performance were observed, we report that caffeine gum enhanced performance on the Yo-Yo IR1 by 2% and increased countermovement jump height by 2.2% when compared to a placebo, but these effects were small.

Improved jumping ability attributed to caffeine ingestion in soccer players supports previous literature (Del Coso et al., 2012; Foskett et al., 2009). Indeed, Foskett et al. (2009) observed that 6 $mg \cdot kg^{-1}$ BM of caffeine ingested 60 min before completing simulated soccer activity enhanced jump height by 2.7%. Similarly, Gant, Ali and Foskett (2010) reported that caffeine doses of 3.7 $mg \cdot kg^{-1}$·BM co-ingested with 1.8 $mg \cdot kg^{-1}$ BM of carbohydrate enhanced countermovement jump performance versus a carbohydrate only drink by 2.3%. In addition, Del Coso et al. (2012) reported that jump height was increased by 3.1% in semi-professional soccer players after consuming 3 $mg \cdot kg^{-1}$ BM of caffeine. The enhancement in jump performance reported previously are similar to what we have reported (2.2%) although our study is the first to examine the effect of lower doses of caffeine (~ 2.7 $mg \cdot kg^{-1}$ BM) administered via a chewing gum. These improvements in jumping could be attributed to increases in force production after caffeine ingestion (Bloms, Fitzgerald, Short, & Whitehead, 2016). It has previously been reported that caffeine ingestion increases both peak torque and the rate of torque development (Duncan, Thake, & Downs, 2014) which are likely to be the mechanisms responsible for enhancing jump height performance.

In contradiction to the jump data, caffeine had no effect on 20 m sprint times; a finding which supports previous studies (Andrade-Souza, Bertuzzi, de Araujo, Bishop, & Lima-Silva, 2015; Astorino et al., 2012) but also contradicts others (Carr, Dawson, Schneiker, Goodman, & Lay, 2008; Del Coso et al., 2012). Admittedly, we only measured sprint time over a single 20 m sprint, whereas studies that have found improvements in sprinting have used repeated sprint protocols. Gant et al. (2010) used the Loughborough intermittent shuttle test, and found that caffeine improved mean sprint times (caffeine: 2.48 ± 0.15 s, placebo: 2.59 ± 0.2 s; $p = 0.04$) over the final 15 min of the 90 min protocol. Del Coso et al. (2012) measured sprint performance using a 7 x 30 m sprint test and highlighted that mean running speed was quicker after consuming 3 mg·kg^{-1} BM of caffeine (caffeine: 25.6 ± 2.1 vs. placebo: 26.3 ± 1.8 km·hr^{-1}; $p < 0.05$). In another comparable study, Carr et al. (2008) reported that ingesting 6 mg·kg^{-1} BM of caffeine 60 minutes beforehand enhanced performance across set 1, 3 and 5 during a repeated sprint performance test consisting of five sets of 6 x 20 m sprints. The lower caffeine dose administered in this study (i.e., 200 mg; where it is assumed that ~ 170 mg was released) may explain the lack of effect in relation to high intensity running performance versus those using higher doses > 3 mg·kg^{-1} BM (Del Coso et al., 2012; Gant et al., 2010; Carr et al., 2008). Additionally, we used a single 20 m sprint to assess performance relative to previous studies that have observed ergogenic effects in repeated sprint protocols (Carr et al., 2008; Del Coso et al., 2012). Intuitively, the likely ergogenic mechanism of caffeine improving repeated sprinting relates to adenosine receptor antagonism and thus reduction in the perception of pain; possibly mediating the challenge of repeated sprint performance versus a single sprint.

This is the first study to show that 200 mg of caffeine delivered via chewing gum can evoke a small 2% (95% CI 0.48%, 3.60%) improvement on the Yo-Yo IR1. Previous studies have found mixed results of caffeine on soccer-specific endurance tests although none have used comparable modes of ingestion. Our findings support Mohr et al. (2011) who found a 16% performance increase; albeit under conditions of a higher caffeine dose (i.e., 6 mg·kg^{-1} BM) using a different variant of the Yo-Yo test. However, these findings are in contrast with other studies that reported no beneficial effects of caffeine on the Yo-Yo IR2 in soccer players (Bassini et al., 2013). Other studies have examined the effects of caffeine supplementation on total distance covered using Global Positioning System (GPS) technology as well as other tests than used here. Del Coso et al. (2012) found that total distance covered at a speed higher than 13 km·h^{-1} during a simulated soccer match was greater after 3 mg·kg^{-1} BM of caffeine when compared to a placebo (caffeine: 1436 ± 326 m, placebo:1205 ± 289 m). The improvements in total distance covered in the Yo-Yo IR1 in our study could be attributed to caffeine's effects on the central nervous system via adenosine receptor antagonism. More specifically, caffeine ingestion inhibits the effects of adenosine on neurotransmission in the brain thereby reducing the perception of effort, increasing arousal, and delaying fatigue (Davis et al., 2003), all aspects that could have enhanced performance on the Yo-Yo IR1. It has previously been reported that caffeine present in chewing gum is primarily absorbed through the buccal mucosa which has an excellent vascular supply and thus an excellent rate of absorption (Kamimori et al., 2002). It is likely that when gum is chewed, some caffeine is released into the saliva that is then swallowed and subsequently absorbed in the gastrointestinal tract. A combination of both methods results in a faster plasma caffeine peak which could explain the performance enhancement observed on the Yo-Yo IR1.

It should be acknowledged that a limitation of this study was that plasma caffeine was not measured, however, Kamimori et al. (2002) have previously reported that chewing caffeine gum for 5 min results in 85% of the caffeine dose being released. In addition, as the caffeinated gum contained 100 mg per piece, it was problematic to prescribe exactly 3 mg·kg^{-1} BM of caffeine as a relative dose to participants, thus we had to provide an absolute dose of 200 mg. Despite this limitation, the mean dosage given was 2.7 ± 0.2 mg·kg^{-1} BM (range: 2.4 to 2.9) of caffeine. It is possible that we may have observed larger effects if we had administered a higher dose of caffeine. A second limitation of this study was that all three performance tests were conducted on the same day with 5 min recovery periods in between each test. However, it is unlikely that three maximal countermovement jumps and a maximal 20 m sprint would result in fatigue and subsequently affect the results of the Yo-Yo IR1 test. Moreover, these tests are typically conducted in the field on the same day when used to test players in the 'real world'. Lastly, we did not determine the reliability of the three tests within our sample to confirm whether the coefficient of variation was similar to previously reported values.

Practical Applications

Chewing caffeinated gum that contains 200 mg of caffeine for 5 min before performing soccer-specific tests can enhance aerobic capacity by 2% and increase countermovement jumping performance by 2.2%. Chewing gum provides an alternative mode of caffeine administration that is more rapidly absorbed (via the buccal mucosa) than capsules and drinks and less likely to cause gastrointestinal distress. Accordingly, this may be beneficial for team sport athletes where there is limited time for nutrition intervention during competition such as at half-time where only 10 minutes are available to administer a nutritional intervention, for substitutes that would come on when called upon by the coach and for players who cannot tolerate caffeinated beverages or capsules because of gastrointestinal distress before kick-off. It is important to acknowledge that caffeine gum should not be used during pre-, mid- and end-season testing in an attempt to enhance performance on the testing battery as this could influence the interpretation of the data. Future studies should investigate the effects of caffeinated gum on technical aspects of soccer as well as actual match play.

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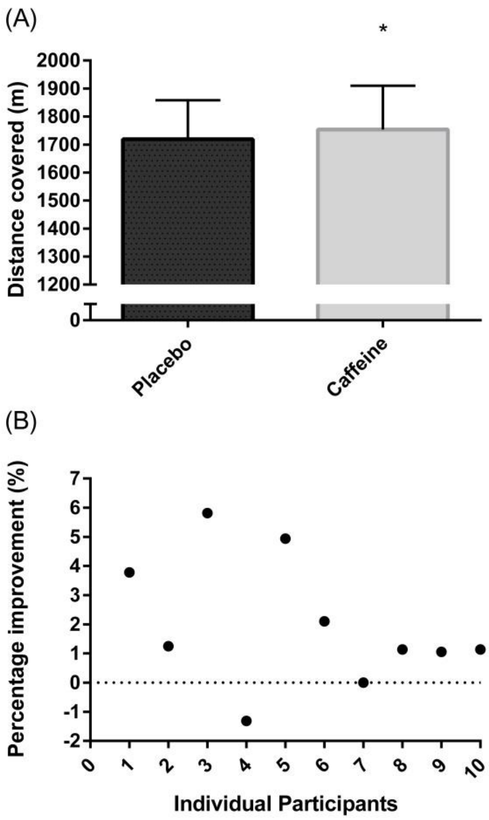
Figure Legends

FIGURE 1. (A) Total distance covered on the Yo-Yo intermittent recovery test level 1 (n = 10). Data are expressed in as mean ± SD. * Caffeine significantly higher than placebo (p = 0.016). (B) Individual participant data on percentage improvement after caffeine ingestion. Dotted line represents no change.

FIGURE 2. (A) Countermovement jump height (n = 10). Lines are individual participant data. Data are expressed in as mean ± SD. * Caffeine significantly higher than placebo (*p* = 0.008). (B) Individual participant data on percentage improvement after caffeine ingestion. Dotted line represents no change.



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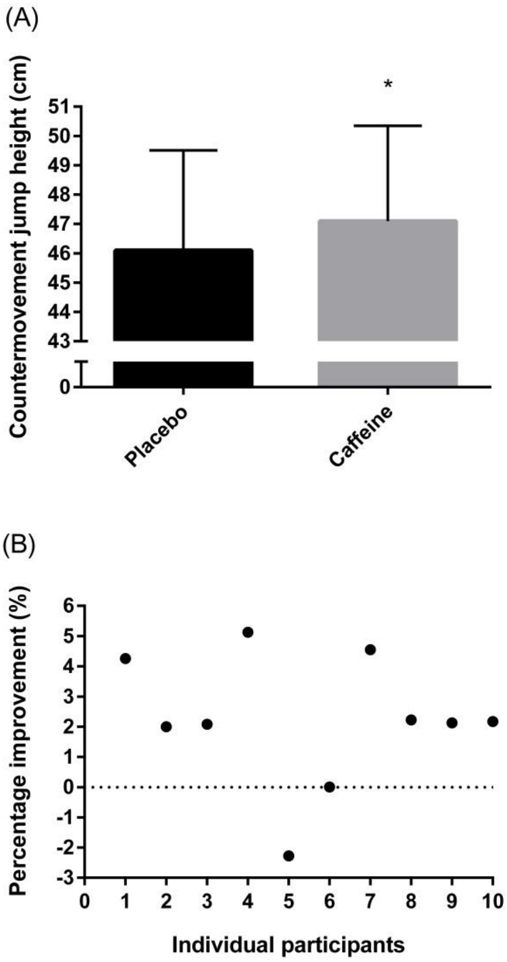

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